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FOR: TRANSPORTING APPARATUS AND TRANSPORTING CONTROL METHOD FOR THIN PLATE

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DESCRIPTION

TRANSPORTING APPARATUS AND TRANSPORTING CONTROL METHOD FOR THIN PLATE

Technical Field

The present invention relates to a transporting apparatus and a transporting control method for thin plates, the transporting apparatus being installed in a given clean environment for transporting or transferring the thin plates such as semiconductor wafers, liquid crystal display units, plasma display units, organic electroluminescence display units, inorganic electroluminescence display units, field emitting display units, liquid crystal display panels, printed-wiring assemblies, and partly-finished products.

Background Art

Conventionally, used as a robot for transporting thin plates in the clean environment is a scalar type robot represented in the Japanese Patent No. 2,739,413. However, in these days, as display units such as liquid crystal display units (liquid crystal display TV) become larger in size, glass plates used therefor also become larger in size, which requires upsizing of a robot for transporting the plates. Accordingly, when glass plates are transported in and transferred to various processing chambers, it is required to prepare a large-sized glass plate of 2 m x 2 m or more in size, lift the plate up by 2 m or more and transport the plate at high speed and accurately.

Since a large-sized thin plate (or glass plate) is heavy and vulnerable to deflection, it is difficult to transport the heavy, large-sized thin plate upward, at high speed and stably. In order to solve this problem, various inventions were proposed.

For example, Japanese Laid-open Patent Publication No. Hei9-505384 discloses a lifting mechanism having multistage ball screws, and Japanese Laid-open Patent Publication No. Hei10-209241 discloses a jack-type lifting mechanism. In addition, Japanese Laid-open Patent Publication No. Hei11-238779 discloses a jointed-arm type lifting mechanism used in robot welders and Japanese Laid-open Patent Publication No. 2001-274218 discloses a robot with a lifting mechanism arranged at the base of two horizontally rotating arms which are opposed vertically.

Disclosure of Invention

Problems to be solved by the invention

However, the multistage ball screw lifting mechanism has a difficulty in withstanding the rolling since the mechanism is poor in strength in the horizontal direction. For the jack-type or jointed-arm type robot, when it brings up the plate against the gravity, much power is required based on the reverse leverage. Further, in order to bear the burden of this power, the arm driving mechanism is required to have a thick and heavy framework, which presents a problem. When a robot having one lifting mechanism at the base of horizontally rotating arms is used, free transporting is permitted only at the arm-attached

side. Therefore, in order to transporting the plate to the opposite side, the lifting mechanism supporting the heavy weight has to be provided with one rotational axis at the bottom thereof to be rotated, which is structurally difficult.

Further, when a robot becomes larger associated with upsizing of thin plates, the robot itself increases in weight and the distance of extended end effectors becomes longer. This is likely to deflect the robot itself in operation (depending operational positions of the end effectors), which makes it difficult to perform transporting operations, including taking out a thin plate of a cassette and inserting the thin plate into a cassette, without considering tilt of the robot by deflection. Here, in the description of the specification of this application, it is assumed that "transporting" of a thin plate from a position A to a position B by a transporting robot means all movement of a thin plate by the transporting robot. For example, "transporting" includes the operation of taking a thin plate out of a cassette to transport it to a processing chamber and the operation of taking a thin plate from the processing chamber back into a cassette,

Furthermore, when a large-sized, largely-deflected thin plate such as glass plate which is used as a plate of a liquid crystal display unit is lifted and held by the end effectors, transported at a high speed and placed on a given position, it is important to place the thin plate at a given reference position properly. When the position where the thin plate is placed on the end effectors is displaced, it becomes difficult

not only to place the thin plate at a correct position but also to perceive the transporting path of the glass plate (thin plate) and deflection accurately, which sometimes causes the thin plate to be brought into contact with other mechanisms to be broken.

Accordingly, it is an object of the present invention to provide a transporting apparatus and a transporting system, the transporting apparatus installed in a given clean environment and capable of providing stable behavior in transporting a large-sized sheet medium upward against the gravity, eliminating the necessity of large power that was required conventionally.

Further, it is another object of the present invention to provide a transporting apparatus and its transporting control method capable of transporting a thin plate accurately even if a robot is deflected.

Furthermore, it is still another object of the present invention to provide a transporting apparatus and its transporting control method capable of detecting whether a sheet medium is held at a proper reference position and calculating displacement of the medium from the proper reference position so as to correct the transporting path.

Means for solving the problem

According to the present invention, a horizontal support table is provided liftable between a pair of upright support members and a robot is placed on the horizontal support table,

having horizontally rotating arms. Further, a tilt adjusting mechanism is provided on the horizontal support table thereby to make the tilt angle of the robot adjustable.

According to a first embodiment of a transporting apparatus of the present invention, the transporting apparatus is installed in a given clean environment, for transporting a large-sized thin plate from a predetermined takeoff position to a processing chamber, and comprises: a pair of upright support members standing and being spaced; at least one horizontal support table liftably cantilevered on the pair of upright support members; lift driving means for lifting the horizontal support table vertically; and a robot placed on the horizontal support table and having horizontally rotating arms for taking up and transporting the thin plate.

In this embodiment, as the robot is supported by the two upright support members and lifted vertically along the upright support members, stable lifting even to a relatively high position is allowed. In addition, a load added to raise the robot does not depend on the current position of the robot.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the robot drives the horizontally rotating arms to take the thin plate from or back to between the pair of upright support members. In this embodiment, as the spacing of the pair of upright support members is set to be larger than the width of the thin plate, it is possible to take the thin plate from between the pair of upright support

members.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the horizontal support table comprises tilt adjusting means for changing an angle of the robot placed on the horizontal support table with respect to a horizontal plane. In this embodiment, as the tilt adjusting means is provided at the horizontal support table which the robot is placed on so as to slightly change the tilt of the robot as a whole, it is possible to change the tilt of the robot. Tilt adjustment is allowed by, for example, taking up or down one point, two points or one side on the table supporting the robot slightly by a cum.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized by further comprising deflection compensating means for compensating a deflected amount in a vertical direction of the rotating arms and a deflected amount of end effectors provided at respective ends of the rotating arms for taking up and transporting the thin plate. In this embodiment, it is possible to compensate deflection caused by upsizing of the thin plate and increase in moving amount of the rotating arms thereby to hold the thin plate accurately and transport it to a target position precisely safely.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the deflection compensating means

compensates both of the deflected amounts when the end effectors take up the thin plate. In this embodiment, compensation is controlled based on the deflected amount depending on whether the thin plate is held or not.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the deflection compensating means comprises deflection storing means for storing deflected amounts in the vertical direction at a plurality of measurement points involved in movement of a reference point on the rotating arms or the end effectors and, every time the reference point moves to one of the measurement points, the deflection compensating means reads a deflected amount corresponding to a present position from the deflection storing means to compensate the deflected amount. In this embodiment, it is possible to perform time-division compensation control based on the deflected amount which is changed with moving distance of the rotating arms. This further enables more efficient transporting operation.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the deflection storing means stores both a deflected amount due to its own weight (hereinafter also referred to as "self weight") and a deflected amount due to holding of the thin plate, and the deflected amount due to self weight and the deflected amount due to holding of the thin plate are used to change a compensation amount.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the deflection compensating means comprises compensation controlling means for controlling the lift driving means to raise or lower the horizontal support table based on the deflected amount thereby to compensate deflection of the rotating arms or the end effectors. In this embodiment, deflection compensation is performed by adjusting the height of the horizontal support table on which the robot is placed based on the deflected amount.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the deflection compensating means comprises compensation controlling means for controlling the tilt adjusting means to tilt the robot placed on the horizontal support table so as to raise or lower the end effectors or the rotating arms thereby to compensate deflection of the rotating arms or the end effectors. In this embodiment, deflection compensation is performed by tilting the robot on the horizontal support table thereby to raise the position of ends of the end effectors.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the deflection compensating means comprises compensation controlling means for controlling the lift driving means and the tilt adjusting means so as to raise or lower the horizontal support table and/or to control the tilt

adjusting means to performed tilting based on the deflected amount thereby to compensate deflection of the rotating arms or the end effectors. In this embodiment, deflection control is allowed by both of adjusting the vertical direction of the horizontal support table and adjusting the tilt of the robot. This enables appropriate and efficient transporting of the thin plate.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized by further comprising: placing position detecting means including a placing position sensor for detecting passage of the thin plate held by the end effectors and calculating means for calculating a displaced amount of the placing position from the reference point based on a detected signal of the placing position sensor; and displacement compensating means for compensating the displaced amount of the placing position based on the calculated displaced amount. In this embodiment, as the displacement of the transporting position due to the displacement of the placing position is prevented, the transporting operation can be performed accurately. In addition, it is possible to prevent accidents such as contacting with another portion due to displacement of the placing position during transporting.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized in that the placing position detecting means calculates a displaced amount in an X axis direction, a

displaced amount in a Y axis direction and a displaced amount in a rotational direction from the predetermined reference point and the displacement compensating means compensates the displaced amounts by moving the end effectors in such a direction that the calculated displaced amounts are cancelled. In this embodiment, it is possible to compensate displacement of the placing position in all of the X direction, the Y axis direction and the rotational direction.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized by further comprising moving means for moving the pair of upright support members horizontally. In this embodiment, as the horizontal support table with the robot placed on is configured to be horizontally movable, the robot is allowed to move in both of the horizontal direction and the vertical direction. This configuration enables the robot to be moved freely to any position within the given space.

According to another embodiment of the transporting apparatus of the present invention, the transporting apparatus is characterized by further comprising a beam for fixedly coupling top portions of the pair of upright support members while the pair of upright support members is held in parallel. In this embodiment, the beam is used to reinforce the position to which the upright support members.

According to a first embodiment of a transporting control method of a transporting apparatus of the present invention, the transporting control method is installed in a predetermined

clean environment and having rotating arms and end effectors, for transporting a large-sized thin plate from a predetermined takeoff position to a processing chamber, comprising the steps of: (a) based on position data of accessed position of the rotating arms and the end effectors, calculating a moving amount in a horizontal direction, a moving amount in a vertical direction and driving data of the rotating arms and the end effectors; (b) moving a robot based on the moving amount in the horizontal direction and the moving amount in the vertical direction and driving the rotating arms and the end effectors based on the driving data; (c) reading from storing means deflection data of the rotating arms and the end effectors which are extended; (d) calculating compensation data for compensating a deflected amount based on the deflection data; and (e) controlling to adjust the moving amount in the vertical direction based on the compensation data thereby to compensate the deflected amount.

According to another embodiment of the transporting control method of the present invention, the transporting control method is characterized in that the step (e) is replaced with the step (f) of adjusting a tilt angle of the robot based on the compensation data thereby to compensate the deflected amount. In this embodiment, deflection is compensated in transporting by adjusting the height of the robot.

According to another embodiment of the transporting control method of the present invention, the transporting control method is characterized in that the step (e) is replaced

with the step (g) of adjusting the moving amount in the vertical direction and/or the tilt angle of the robot based on the compensation data thereby to compensate the deflected amount. In this embodiment, deflection is compensated by changing the tilt angle of the robot thereby to change the positions of the end effectors.

According to another embodiment of the transporting control method of the present invention, the transporting control method is characterized in that the deflection data read in the step (c) includes deflection data at a plurality of moving points of the rotating arms and the end effectors and the compensation data calculated in the step (d) includes compensation data at each of the moving points. In this embodiment, deflection is compensated by adjusting the height and/or the tilt angle of the robot.

According to another embodiment of the transporting control method of the present invention, the transporting control method is characterized in that in the step (c), the deflection data read from the storing means depends on whether the thin plate is held or not. In this embodiment, deflection compensation data varies depending on whether the end effectors hold the thin plate or not.

According to another embodiment of the transporting control method of the present invention, the transporting control method is characterized in that in the step (c), read from the storing means is the compensation data calculated and stored in advance based on the deflected amount; calculating

of the compensation data in the step (d) is not performed; and processing in the step (e) is performed based on the read compensation data. In this embodiment, deflection is compensated by calculating in advance compensation data of a deflected amount corresponding to each of the moving positions and reading out the compensation data. Accordingly, it becomes possible to eliminate the necessity to calculate compensation data in moving operation, thereby reducing the load on the controller and increasing the processing speed.

According to another embodiment of the transporting control method of the present invention, the transporting control method is characterized by further comprising the steps of: (h) detecting a placing position of the thin plate held by the end effectors; (i) comparing the placing position and a predetermined reference placing position to calculate a displaced amount; and (j) performing operational control to compensate the displaced amount.

According to another embodiment of the transporting control method of the present invention, the transporting control method is characterized in that the displaced amount in the step (i) includes a displaced amount in an X axis direction, a displaced amount in a Y axis direction and a displaced amount in a rotational axis direction from the reference placing position, and the operational control in the step (j) is performed to compensate each of the displaced amounts in the step (i).

Brief Description of Drawings

Fig. 1 is a plane view illustrating a sheet manufacturing system comprising a transporting apparatus according to an embodiment of the present invention;

Fig. 2 is a perspective view of the transporting apparatus 10 shown in Fig. 1;

Fig. 3 is a cross sectional view seen from the line A-A' of Fig. 1;

Fig. 4A is a side view illustrating an example of lifting mechanism of towers (upright support members);

Fig. 4B is a cross sectional view seen from the line B-B' of Fig. 4A;

Fig. 5 is a side view of a transporting apparatus illustrating another example of lifting mechanism provided at the towers;

Fig. 6 shows the operating range (direction) of the robot and its end effectors;

Fig. 7A is a side view showing an example of tilt adjusting means;

Fig. 7B is a side view showing an example of tilt adjusting means;

Fig. 7C is a side view showing an example of tilt adjusting means;

Fig. 8 is a side view showing tilt adjusting means according another embodiment;

Fig. 9 is a pattern diagrams illustrating concept of tilt adjusting means according another embodiment;

Fig. 10A is a graph of a deflection curve line D showing deflected amounts obtained when a measurement point (reference point) on the end effector moves from the measurement point A to the measurement point J during the rotating arms being extended;

Fig. 10B is a graph showing a deflection curve line and an interpolation curve line for compensating the deflection;

Fig. 11 is a functional block diagram illustrating transporting control means for controlling transporting in the horizontal direction and vertical direction according to an embodiment of the present invention;

Fig. 12A is a view illustrating maximum transporting distance of the end effectors 17 by rotating arms;

Fig. 12B illustrates end effectors 17 being inserted into a predetermined storage when deflected amount is not compensated;

Fig. 12C illustrates deflected amount being compensated by tilt adjusting portion;

Fig. 13 is a plain view illustrating a transporting position of thin plate by a robot;

Fig. 14 is a perspective view showing a transporting apparatus comprising placing position detecting means according to an embodiment of the present invention;

Fig. 15 is a view illustrating a placing position (teaching position) at which the end effectors hold a glass plate in a X-Y plan (horizontal plane) having a pivot center of the robot as original point;

Fig. 16 is a diagram illustrating displacement in the X axis direction of the placing position from the teaching position;

Fig. 17 is a diagram illustrating displacement in the Y axis direction of the placing position from the teaching position;

Fig. 18 is a diagram illustrating relationship between the teaching position and the placing position when the placing position is displaced from the teaching position in the X axis direction, the Y axis direction, parallel direction and the rotational direction;

Fig. 19 illustrates the state shown in Fig. 18 being rotated by the angle α toward the teaching direction;

Fig. 20 is a view illustrating the teaching position where two position detecting sensors;

Fig. 21 is a view explaining a manner of calculating a displacement in the rotational direction from the teaching position by measured value by the two position detecting sensors; and

Fig. 22 is a partial perspective view for explaining an embodiment for preventing dust pollution in the clean environment.

Description of the Symbols

10 transporting apparatus

11 moving table

12 tower (upright support member)

13 horizontal support table

14 transporting robot

16 rotating arm

17 end effector

27 lifting motor

30 tilt mechanism (tilt adjusting means)

40 base table

41 moving table

42 rail

50 stage

60 processing chamber

77 vertical driving means

80 exhaust pipe

81a to 81f rotational axis

82a to 82e exhaust duct

110 position detecting sensor

Best Mode for Carrying out the Invention

With reference to the attached drawings, embodiments for carrying out the present invention will be described in detail below. The following description deals with the case for transporting a glass plate of about 2 m square as a thin plate. As a transporting apparatus of the present invention is an apparatus for transporting a sheet member used in manufacturing a semiconductor integrated circuit, the transporting apparatus is operated in an environment of certain cleanness which is lower than that of clean room. Accordingly, the transporting

apparatus of the present invention is a transporting apparatus which meets predetermined requirements for operating in the clean environment, for example, prevention of dust from occurring, and is completely different in behavior from transporting apparatus including a normal crane vehicle and a lifting machine in a storage warehouse.

Fig.1 is a plane view illustrating a sheet manufacturing system for semiconductor integrated circuits, having a transporting apparatus according to an embodiment of the present invention. The sheet manufacturing system includes a transporting apparatus 10, a stage 50 arranged in front of the transporting apparatus 10, and a processing chamber 60 arranged behind the same.

Fig. 2 is a perspective view of a transporting apparatus according to another embodiment of the present invention, in which only a configuration of the horizontal support table is different from that of the transporting apparatus 10 in Figs. 1 and 3. Fig. 3 is a cross sectional view seen from the line A-A′ in Fig. 1. Mounted on the stage 50 are a cassette 51 having a glass plate 53and an empty cassette 52.

The transporting apparatus 10 takes out a glass plate 53 from the cassette 51 (Fig. 3) and transfers it to the rear processing chamber 60, in which the glass plate is subjected to processing in accordance with a given purpose. The treated glass plate 53 is taken out by the transporting apparatus 10 and transported into the empty cassette 52. The cassettes 51 and 52 are transported by an AGV (Automotive Ground Vehicle)

or the like and arranged on a given position of the stage or transported out thereof.

The transporting apparatus 10 includes a base table 40, a pair of upright towers (upright support members) 12, a horizontal support table 13 supported liftably by the pair of towers 12, and a robot 14 placed and fixed onto the horizontal support member 13. The base table 40 includes three rails 42 extending right and left, and a movable table 11 provided movable right and left (in the direction of X axis) on the rails 42.

The pair of towers 12 is provided on the moving table 41 and horizontally movable in the right and left direction (in the direction of X). The spacing of the pair of towers 12 is small enough for the thin plate to pass between the pair of towers and the height of the towers is determined depending on the height of a cassette for receiving a transferred glass plate and the height of the plate processing chamber. In addition, the pair of towers 12 is preferably coupled and reinforced by a beam at the top thereof to form like a gate.

The horizontal support table 13 is mounted on the pair of towers 12. The horizontal support table 13 is cantilevered by the pair of towers 12 so as to protrude toward the processing chamber 60 and is liftable along the pair of towers 12. The horizontal face of the horizontal support table 13 used as a table is as small as possible, and is preferably in the shape of "minoko type plate" (curved plate) or perforated plate. Since dust attached to a thin plate to be transported reduces

a yield (good item rate) and therefore, the thin plate requires a manufacturing environment of high cleanness, it is preferably to reduce as much as possible disturbance of air during lifting so as to prevent disturbance in the environment of the factory.

Placed and fixed onto the horizontal support table 13 is a robot 14. The robot 14 has two rotating arms 16 which are rotatable around joints. Each of the rotating arms 16 has at an end thereof an end effector 17 for transporting a glass plate 53.

When the glass plate 53 is taken out of the cassette 51, the moving table 41 to which the pair of towers 12 is fixed is moved in the horizontal direction (x axis direction), the horizontal support table 13 is moved up and down (in the Z axis direction) to adjust the height, and thereby, the robot 14 is moved in front of the cassette 51 in which the glass plate is received. When the glass plate 53 is taken out of the cassette 51, the rotating arms 16 are driven to insert the end effectors 17 into the cassette 51, then, the horizontal support table 13 is moved up by predetermined height (slightly) and thereby the glass plate 53 is taken up.

Then, the end effectors 17 are drawn close to the body of the robot 14 (in the Y axis direction), the robot 14 is rotated by 180°, and the moving table 41 and the horizontal support table 13 are moved in the X and Z axes directions, respectively, to be stopped in front of the processing chamber 60. Then, the gate 61 is opened to extend the arms 16 so as to insert the end effectors 17 into the processing chamber 60 and place the glass

plate 53 on. After processing on the glass place 53 is finished, the end effectors 17 are used to take the glass plate out of the processing chamber 60 and store it in the other cassette 52.

The robot having rotating arms used in the present invention includes a scalar type robot having horizontally turning arms and a multijoint type robot having joints rotating in the vertical plane or around an axis in the arm direction. The robot placed on the horizontal support table 13 may be configured to have a lifting mechanism on itself for fine adjustment in the vertical direction. Provision of the robot itself with a lifting mechanism presents an advantage that fine adjustment in the Z axis direction becomes possible. However, it also presents problems that the robot configuration becomes complicated and the upward load on the horizontal support table is increased due to increase in weight.

The robot also used in the present invention has the end effectors 17 for placing a thin plate, which end effectors 17 each can be provided with an absorbing mechanism. The shape of the absorbing mechanism may be publicly well-known. Further, the joint is subjected to sealing by magnetic fluid and all the coupling portions are preferably configured to prevent dust in the robot from coming out of the robot by use of packing.

As described above, the pair of towers 12 has the horizontal support table 13, on which the robot 14 is placed and the horizontal support table 13 is moved in the up and down direction (Z axis direction). The pair of towers 12 is fixed

to the moving table 41 to be moved in the horizontal direction (X axis direction). Further, the horizontal support table 13 includes a tilt mechanism (tilt adjusting means) 30 (Fig. 3), and the robot 14 is arranged via the tilt adjusting means. The following description is made about means for moving in the X axis direction, moving means in the Z axis direction and tilt adjusting means of the transporting apparatus according to an embodiment of the present invention.

(Means for moving in the X axis direction)

With use of Figs. 1 and 3, the configuration of the base table 40 and motion in the X axis direction of the pair of towers 12 fixed to the base table 40 are described. The base table 40 is provided with a moving table 41 slidable on three rails 42, and fixed onto the moving table 41 is the pair of towers 12. On the moving table 41 a motor 19 is fixed, and a pinion attached to the motor 19 and a rack attached to the rail 42 enable movement in the X axis direction. The motor 19, the rack and pinion may be attached to either of the rails 42, and preferably to the center one of the rails 42.

This horizontally moving mechanism adopted here includes a system of horizontally parallel rails and rack-and-pinion, a cableway system, a ball screw rail system, a rail running system, an air-cushion system, a magnetic levitation system and other well-known heavy lifting systems. A driving source of such a horizontally moving mechanism used here includes a servo motor, a stepping motor, a linear motor, a fluid pressure

cylinder of hydraulic pressure or air pressure and other well-known driving sources.

(Means for moving in the Z axis direction)

The pair of towers 12 has at least a function of supporting the horizontal support table 13 on which the robot 14 is arranged and a function of moving the horizontal support table 13 in the up and down direction (Z axis direction). Driving in the up and down direction is performed by a guide portion for assuring accurate motion in the up and down direction and a lift driving portion. An example of the specific mechanism is described with use of Figs. 4A and 4B.

Fig. 4A is a lateral view showing an example of the lifting mechanism provided on the towers (upright support members) 12. Fig. 4B is a cross-sectional view seen from the line B-B′ shown in Fig. 4A. In Fig. 4A, the lifting motor 27 rotates a coupling axis 26 via a bevel wheel. The coupling axis 26 rotates a pole type screw 25 provided in each of the pair of the towers 12 via a bevel wheel provided at the bottom of each of the towers 12.

The screw 25 is engaged with a screw bearing 28 fixed to the horizontal support table 13. When the screw 25 rotates, the screw bearing 28 moves up and down in accordance with the rotation direction of the screw 25. Accordingly, rotation of the screw 25, via the screw bearing 28, causes the horizontal support table 13 to move up and down along a corresponding linear guide 24. Since as described above, the robot is placed on the horizontal support table 13, the height of the rotating arms

16 and end effectors 17 of the robot 14 can be adjusted in the Z direction. The horizontal support table 13 is movable from the highest H to the lowest L.

Here, the guide portion used here includes a bearing, a roller and guide mechanism for arranging a rotary member such as a roller along a reference rail, a contact guide mechanism making use of magnetic repulsive force or air film, and the like. The lifting mechanism used here may be a ball screw, a rack and pinion, a pulley, suspending ribbon and balance bell, rod or rodless air balance cylinder, any type or brakes and other well-known driving portions.

(Other examples of means for moving in the Z axis direction)

Fig. 5 is a lateral view of a transporting apparatus illustrating another example of a lifting mechanism provided at the pair of towers 12. This lifting mechanism has an air balance cylinder 34 in order to minimize energy. Around a motor provided at the bottom of the tower 12 and a sprocket 32 provided close to the top of the tower 12, a ring chain 33 is hung. To the left of the chain 33, the air balance cylinder 34 is arranged. The horizontal support table 13 moving as guided by the linear guide 24 and the chuck of the air balance cylinder 34 are coupled to the chain 33 and air pressure corresponding to the weight of the horizontal support table 13 with the robot 14 placed on is applied to the cylinder 34. The horizontal support table 13 is movable from the lowest position L to the highest position H.

(Movable range by robot 14)

Fig. 6 shows an operating range of the robot 14 and end effectors 17. The pair of rotating arms 16 and the end effectors 17 provided at the respective ends thereof are accessible to the processing chamber 60 arranged within a sector range of approximately 220° to the right side of the pair of towers 12 in Fig. 6. To the left side of the pair of towers 12 in Fig. 6, once the robot 14 is turned, the end effectors 17 become accessible to the cassettes 51 and 52 between the pair of towers 12. If the two end effectors 17 are operated simultaneously, the transporting speed of a sheet can be doubled.

(Tilt adjusting means)

As shown in Fig. 3, the horizontal support table 13 has a tilt mechanism (tilt adjusting means) 30, and the robot 14 is arranged on the horizontal support table 13 via the tilt adjusting means. The tilt adjusting means is provided for adjusting the tilt angle of the robot 14 within an angle "T". Figs. 7A through 7C are lateral views illustrating examples of the tilt adjusting means 30.

The tilt adjusting means 30 includes a tilt table 31 attached pivotable to a hinge portion 35 fixed to the horizontal support table 13 and a tilt driving mechanism. The tilt driving mechanism includes a pole-type screw 36, a bearing screw 37 engaged with the screw 36, a rotation driving portion 45 for rotating and counterrotating the screw 36 and a bearing 46.

When the rotation driving portion 45 rotates the screw 36, the bearing screw 37 moves left or right in accordance with the rotating direction of the screw 36. The bearing screw 37 has a sliding hinge 38 attached thereto and the sliding hinge moves along a sliding guide 39. This moves a left end of the tilt table 31 upward and downward and thereby the angle of the upper face of the tilt table 31 becomes changed. Since the robot 14 is fixed to the upper face of the tilt table 31, the horizontal tilt of the robot 14 is changed following the angle change of the tilt table 31.

Fig. 7B shows angle change when the screw 36 with a clockwise rotating screw is rotated clockwise. When the screw 36 rotates clockwise, the bearing screw 37 moves in the left direction and the left end of the tilt table 31 moves downward. Fig. 7C shows angle change when the screw 36 is rotated counterclockwise. When the screw 36 rotates counterclockwise, the bearing screw 37 moves in the right direction and the left end of the tilt table 31 moves upward.

(Other examples of tilt adjusting means)

Fig. 8 illustrates another example of the tilt adjusting means. In this example, the angle of a tilt table 71 coupled pivotable to a hinge portion 72 changes by driving a cam 73.

Further, Fig. 9 illustrates another example of the tilt adjusting means. In this example, the tilt angle can be changed 360° in the horizontal plane. The tilt table 76 is supported by three parts composed of a fixed position rotational axis 79,

and vertical driving means 77 and 78. The fixed position rotational axis 79 is fixed in position and is rotatable 360° in the horizontal direction and 90° in the vertical direction. The vertical driving means 77 and 78 have driving means 77a and 78b of oil pressure or the like and driving axes 77b and 78b, which move upward and downward the tilt table 76 by the driving means 77a and 78a. In this configuration, end portions 77c and 78c of the driving axes 77b and 78b move the tilt table 76 upward and downward. The fixed position rotational axis 79 is fixed at the upper and lower positions, the two points are freely movable upward and downward, which allows tilt to be controlled 360° in the horizontal direction including back and forth and around directions.

(Deflection compensation)

A transporting apparatus according to the present invention transports a large-size thin plate. Then, the robot 14 becomes large sized and the rotating arms become weighted. When the rotating arms are extended, the centers of the end effectors can be extended 4,000 mm or more from the center of the robot. The self-weight of the rotating arms and the weight of the thin plate deflect the rotating arms which makes the edges of the end effectors lowered from the original positions. This sometimes makes it difficult to take the thin plate out of a predetermined position inside the cassette precisely and to place it on the accurate position. Accordingly, in order to transport the thin plate accurately and safely, it is preferable

to compensate the distortion.

Fig. 10A is a graph of a deflection curve D showing deflected amounts when a measurement point (reference point) on the end effector moves a measurement point A to a measurement point J in extending the rotating arm. The straight line S in the graph shows a movement trace with no deflection and a deflection curve D shows that a deflected amount is 0 at the point A and continues to be increased to be a maximal deflected amount d at the point J.

In another embodiment of the present invention, in order to transport a thin plate to a target plate accurately and safely, this deflection is controlled to be compensated. Deflection control is performed to cancel the deflection shown in Fig. 10A. More specifically, the horizontal support table 13 is moved upward in such a manner that the movement traces a line in line symmetry with the curved line with respect to the straight line S as shown in Fig. 10A so as to cancel the deflection thereby compensating the deflection in the Z axis direction.

However, the graph of Fig. 10A is only a line chart plotted with deflected amounts at measurement points A to J. Therefore, a difference from an actual deflected amount at each of the measurement points is likely to cause a trouble of oscillating in the vertical motion. Then, interpolation control is performed to make the line chart match the curved line, which is used as a basis to perform compensation. This smoothes extending operation of the rotating arms. The interpolation control is performed for example in a method of performing at

each measurement point the operation of calculating the radius of a circle including deflected amounts at three adjacent points. This operation executed allows a curved line analogous to the line chart to be obtained. In this way, a smooth curved line C shown in Fig. 10B can be obtained, and by driving in the Z axis direction based on this curved line, smooth compensated is allowed to be performed.

(Transporting driving control)

Fig. 11 is a functional block diagram of transporting control means according one embodiment of the present invention. A transporting controller 120 accesses the thin plate and controls motion in the horizontal direction (X axis direction), motion in the vertical direction (Z axis direction), tilt angle of the robot 14, rotation of the robot 14 and the operation of rotating arms 16 in order to transport the thin plate to a target position. Motion in the Z axis direction is performed by lift driving means 121, while motion in the X axis direction is performed by horizontally moving means 130. This configuration enables the robot 14 as a whole to be transported to a predetermined position.

Robot controlling means 135 controls rotation of the robot and the operation of the rotating arms. Further, the tilt adjusting means 125 is used to adjust the tilt angle of the horizontal support table 13. Each moving mechanism and each part of the robot are provided with various sensors 138, and a detected signal is fed back to the transporting controller

120.

When the transporting controller 120 receives transporting control data such as position data indicating a location where a thin plate exists and a transporting position, the transporting controller 120 calculates a moving direction and a moving amount from the data of the current position and the received position data. The calculated movement amount data is divided into horizontal direction data and vertical direction data, which are output to respective driving control means. The moving amount data in the X axis direction is output to the horizontally driving controller 131 and is used as a basis to drive a horizontally driving portion 132. The moving amount data in the Z axis direction is output to the vertical driving controller 122 of the lift driving means 121 and is used as a basis to drive a lift driving portion 123. The robot 14 moves to a predetermined position in the X axis direction and in the Z axis direction.

The robot controller 136 drives an arm driving portion 137 based on the data from the transporting controller 120 to operate the rotating arms 16 and the horizontally rotating operation.

The transporting controller 120 shown in Fig. 11 further includes deflection compensating means 140. The deflection compensating means 140 receives current position information of the robot 14 and operational position information of the rotating arms from the transporting controller 120 to adjust the height of the edge of each of the end effectors 17 for

deflection compensation. The deflection compensating means 140 includes a compensation information calculating portion 141 for calculating a compensation amount for compensating deflection and a deflection information storing portion 143 for storing deflection data of each measurement point when the rotating arms 16 are extended. The compensation information calculating portion 141 reads a deflected amount (compensation amount) measured in advance from the deflection information storing portion 143 in accordance with the received position information and the like and calculates data to be compensated.

The calculated compensation data is output to the lift driving means 121 or the tilt driving controller 126. The vertical position of the horizontal support table 13 or the tilt angle of the robot 14 is changed thereby to compensate the deflected amounts. Driving of the horizontal support table 13 and change of the tilt angle of the robot 14 may be both performed thereby compensating the distortion more accurately.

An example of compensating a deflected amount by use of a tilt adjusting portion is described specifically with reference to Figs. 12A to 12C. Fig. 12A is a view illustrating a maximal transfer distance of the end effectors 17 by the rotating arms 16. The maximal transfer distance of the rotating arms 16 is a distance (m) from a state 100 where the end effectors 17 are held close to the center of the robot to a state 101 where the rotating arms 16 are extended to draw out the end effectors 17 further. As the transfer distance becomes further, the deflection of the rotating arms 16 becomes larger.

Fig. 12B is a view illustrating a case of inserting the end effectors 17 into a predetermined cassette 51 when deflection is not compensated. In this case, if the rotating arms 16 are only driven to extend the end effectors 17 straight in the horizontal direction, the end effectors 17 are likely to hit the cassette 51.

Fig. 12C is a view illustrating a case where the tilt adjusting portion 30 is used to compensate deflection. When the tilt adjusting portion 30 is used to increase the tilt angle slightly, the rotating arms 16 extends while keeping a predetermined tilt angle thereby to raising the position of the end effectors 17, which enables the end effectors 17 to be prevented from hitting the cassette 51.

(Operation checking experiments)

A transporting apparatus of shape shown in Figs. 2, 4 and 13 was manufactured with the following specifications and operated actually for operation check. Fig. 13 is a plain view for illustrating a transporting position of a thin plate by the robot 14. The robot 14 is, as shown in Fig. 5, capable of transporting the plate horizontally within 220° and processing chambers are provided in four directions, respectively, for operation check.

The towers 2 are 4,250 mm in height, 3,820 mm in width between the tower outer walls, 2,620 mm in width between the tower inner walls and 600 mm x 500 mm in tower width, and the corners to the robot side of towers are cut off.

Three rails are prepared (distance between the rails 830 mm and 2,000 mm), each is of 6,500 mm in length, the rail width 33 mm x the height of the rail upper surface is 220, the shelf portion 3 is tower side lifting beam is 2,700 mm, having a bottom of 400 mm in width and 1,800 mm in length.

The robot 4 is a double arm robot with common first arm (boomerang-type robot), and the main body of the robot is arranged at the center of the shelf portion 1400 mm far from the center of the towers. The height of the robot is 880 mm, the diameter of the robot body is 800 mm, the length of the arm is 1,625 mm in minimal rotational radius (1,450 mm in distance between centers of joints) and the first arm open degree is 130°. The end effectors are operated linearly by a pulley and belt provided at the arm joints from the robot center axis.

The tilt mechanism has the following specifications: two worm-gear motors are arranged 60° rightward and leftward relative to the line perpendicular to the rails from the robot center, tilting is set freely 360°, and maximal tilt angle (tilt adjusting angle) is +/- 2°.

Each of the end effectors is 2,310 mm in length, 1,260 mm in width of finger portion (60 mm x 4 finger portions) x 1,800 mm in length.

The capacity of this transporting apparatus is 1,100 - 3,600 mm in transporting-allowed lifting range, 2,500 mm/3.5 seconds in lifting time, and 2,500 mm in horizontally moving distance. The rotational angle of the robot is 500°, rotational speed is 180 degree/2 seconds and tilt speed +/- 2°/second. As

shown in Fig. 6, the maximal transporting distance of one arm of the robot is 4,150 mm while the center of the end effector can extend 4,300 mm far from the center of the robot. Its speed is 4,150 mm/3 seconds. Transporting-in or transporting-out direction of the robot 14 is in the four directions P, Q, R and S shown in Fig. 7. Since the towers 12 are moved by the horizontally moving mechanism 5 having rails, the transporting destination can be freely set as far as the horizontally moving distance is within 2,730 mm.

This transporting apparatus is used to transport a glass plate of 0.7 mm in thickness x 2,000 mm in width x 2,200 mm in length from the cassette 51 (2,200 mm in width x 2,400 mm in depth x 1,600 mm in height, 1,200 mm in height of the bottom stage and 2,720 mm in height of the top stage) to a temporal table in the processing chamber 60 of 1,600 mm in height. After processing, the gate 61 is opened, the robot 14 of the present invention takes out the glass plate 8 and stores it into the cassette 52. Although only one horizontal support table 13 is provided in the description above, there can be provided a plurality of horizontal support tables 13 each of which a robot can be placed on.

(Calculation and compensation of displacement of thin plate placing position)

Further, the transporting apparatus of the present invention may be provided with the following placing position detecting means. First, as shown in Fig. 13, a thin plate

detectable position detecting sensor 110 is provided at a predetermined position in the transporting apparatus. When the end effectors hold the thin plate by adsorption, they transport the thin plate in such a manner that adjacent two sides of the held plate follow a given circular arc which passes over the position detecting sensor 110. Then, the timing of detection by the sensor and the size and shape of the thin plate known in advance are used to determine whether the thin plate is held properly by the end effectors.

With this configuration, positional displacement of the thin plate on the end effectors is detected and for example, controlling means can be used to detect the positional displacement. In other words, the preset teaching position and the actual position are compared to calculate displacement. Here, calculated are distance and angle. However, calculation of displaced angle requires using of a plurality of sensors or plural times of detection by one sensor to obtain necessary position information.

This method is advantageous in that it is possible to judge whether or not the thin plate is held properly by making the plate pass over the at least one position detecting sensor 110 only once. If this transporting for judgment is included into normal transporting, the judgment can be performed more efficiently. The sensor used here includes a line sensor and a spot sensor, and a known optical noncontact sensor is preferably used.

Figs. 14 to 21 are used to explain in detail an apparatus

and method for detecting the placing position of the thin plate by the end effectors and compensating displacement of the placing position. In the following example, a glass plate is transported as the thin plate.

Fig. 14 is a perspective view illustrating an example of a transporting apparatus provided with placing position detecting means of the present invention. Figs. 15 to 21 are views for explaining analysis of the glass plate placing position by the end effectors in the X-Y plane (horizontal plane) where the rotational axis of the robot is the original point.

The transporting apparatus as shown in Fig. 14 is provided with the placing position detecting means. The placing position detecting means includes a position detecting sensor provided on the horizontal support table 13 and a position calculating portion for calculating displacement of the thin plate held by the end effectors 17 based on a detected signal from the position detecting sensor. The position calculating portion is capable of calculating by a conventional microprocessor consisting of a CPU, other logic circuits, memory and control program (including operational program). As such calculating by the microprocessor is well known, further description about the configuration of the microprocessor is omitted here. Description about a calculating manner is given later.

The position detecting sensor has a light emitting portion and a light receiving portion opposed to each other at

horizontally projected portions which are spaced apart vertically. The position detecting sensor detects presence of a blocking object by judging whether light from the light emitting portion is received by the light receiving portion or not(the optical path from the light emitting portion to the light receiving portion is blocked or not). Accordingly, if the transporting path used when the glass plate taken out of the cassette is transported to the processing chamber or when the glass plate is returned back from the processing chamber to the cassette by the end effectors is set in such a manner that at least one side of the glass plate crosses the optical path of the position detecting sensor, the position detecting means is allowed to detect the position of the glass plate on the end effectors.

(Glass plate position measuring method by placing position detecting means)

As shown in Fig. 13, the robot 14 is capable of transporting the glass plate taken from the cassette 51 to the processing chamber 60 which is within the angle of 180° in the opposite direction to the cassette 51. In Fig. 13, as one example, there are provided processing chambers 60 in three directions. When the robot 14 takes the glass plate out of the cassette 51, the glass plate is transported in such a manner that at least one side of the glass plate follows a given path crossing the optical path of the position detecting sensor 110. Figs. 15 to 21 show a detected glass plate when the glass plate

is held by the end effectors and the robot 14 is rotated in the horizontal direction at a given reference position. In these figures, the X-Y plane is shown in which the rotational axis of the robot is set as an original point and the initial position O (r, 0) is given on the X axis.

The placing position detecting means is capable of obtaining the position of the glass plate from the position information of the end effectors by a controller of the robot and detection information of the glass plate detected by the position detecting sensor to calculate displacement of the measurement position from the teaching position. The position detecting means measures operational angles of the robot obtained when the robot is rotated from the initial position O (r, 0) to the positions detected by the sensor of the placing position detecting means, such as the position P1 (XP1, YP1) on the edge of the glass plate, the positions P2 (XP2, YP2) and P3 (XP3, YP3) on one side crossing the side including P1 at right angles, and the position P4 (XP4, YP4) on one side crossing the side including P2 and P3 at right angles (the angles are hereinafter referred to as "measurement angles θP1, θP2, θP3 and θP4") (See Figs. 16 to 19).

The measurement results are transferred to and stored in storing means. These stored measurement results and the teaching position stored in advance in the storing means are transferred to the calculating means when necessary to calculate displacement. If the position information is detected much in variety and amount, it becomes possible to

detect displacement in the direction (X axis direction in the figures) perpendicular to the direction (Y axis direction in the figures) in which the glass plate is transported or the end effectors are operated by the robot, and displacement in the rotational direction (θ direction in the figures). The description below is made about a displaced amount calculating method based on detected position information.

(Teaching method of reference placing position)

Fig. 15 illustrates the angle and position (hereinafter referred to as "teaching position") of each side of the glass plate detected by the position detect sensor 110 when the end effectors hold the glass plate at the preset reference position. When the glass plate is held at the reference position and the end effectors are moved to an initial position, the robot 14 is turned to measure the angle $\theta Q1$ from the initial position to the position for detecting the edge of the glass plate. This result is stored in the storing means as a teaching angle $\theta Q1$. This information is used as a basis to calculate a teaching position Q1 ($XQ1$, $YQ1$) by the calculating means. An equation for calculating this teaching position Q1 ($XQ1$, $YQ1$) is given as follows. In the equation, r is a distance from the rotational center of the robot to the optical axis of the sensor.

(Equation 1)

$$\begin{pmatrix} X_{Q1} \\ Y_{Q1} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{Q1} & -\mathrm{Sin}\theta_{Q1} \\ \mathrm{Sin}\theta_{Q1} & \mathrm{Cos}\theta_{Q1} \end{pmatrix} \begin{pmatrix} r \\ 0 \end{pmatrix}$$

From this equation, the teaching position Q1 (XQ1, YQ1) can be calculated. Further, this teaching position Q1 (XQ1, YQ1) may not be measured value but desired coordinates set in advance in the storing means.

The angles of Q2, Q3 and Q4 are measured in the same way to calculate teaching positions.

(Calculating method of displacement in the X axis direction)

A calculating method of displacement in the X axis direction is described with reference to Fig. 16 in which the solid line shows an actual placing position and the broken line shows the teaching position. In Fig. 16, the glass plate on the end effectors is displaced in the X axis normal direction from the teaching position. The sensor is relatively turned to measure an operating angle of the robot (hereinafter referred to as "measurement angle θP1") from the initial position to the position P1 (XP1, YP1) where the glass plate crosses the optical axis. As is the case with the teaching angle, the glass plate position P1(XP1, YP1) is calculated as follows.

(Equation 2)

$$\begin{pmatrix} X_{P1} \\ Y_{P1} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{P1} & -\mathrm{Sin}\theta_{P1} \\ \mathrm{Sin}\theta_{P1} & \mathrm{Cos}\theta_{P1} \end{pmatrix} \begin{pmatrix} r \\ 0 \end{pmatrix}$$

This result is used to calculate a displaced amount ($\Delta XP1$, $\Delta YP1$).

(Equation 3)

$$\begin{pmatrix} \Delta X_{P1} \\ \Delta Y_{P1} \end{pmatrix} = \begin{pmatrix} X_{P1} \\ Y_{P1} \end{pmatrix} - \begin{pmatrix} X_{Q1} \\ Y_{Q1} \end{pmatrix}$$

From this calculation result of displacement a displaced amount in the X axis direction of the glass plate on the end effectors $\Delta XP1$ ($|XP1-XQ1|$) is calculated.

(Calculating method of displacement in the Y axis direction)

A calculating method of a displacement in the Y axis direction is described with reference to Fig. 17 in which the solid line shows an actual placing position and the broken line shows the teaching position. In Fig. 17, the glass plate on the end effectors is displaced in the Y axis normal direction from the teaching position. As is the case with displacement in the X axis direction, a measurement angle $\theta P2$ of the robot from the initial position to the point P2 on a side perpendicular to the side including P1 is measured. This P2 ($XP2$, $YP2$) is used to calculate a displaced amount in the Y axis direction

as follows.

(Equation 4)

$$\begin{pmatrix} X_{P2} \\ Y_{P2} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{P2} & -\mathrm{Sin}\theta_{P2} \\ \mathrm{Sin}\theta_{P2} & \mathrm{Cos}\theta_{P2} \end{pmatrix} \begin{pmatrix} r \\ 0 \end{pmatrix}$$

When the coordinates of the teaching position Q2 are (XQ2, YQ2), a displaced amount in the Y axis direction ΔY (ΔXP2, ΔYP2) is given as follows.

(Equation 5)

$$\begin{pmatrix} \Delta X_{P2} \\ \Delta Y_{P2} \end{pmatrix} = \begin{pmatrix} X_{P2} \\ Y_{P2} \end{pmatrix} - \begin{pmatrix} X_{Q2} \\ Y_{Q2} \end{pmatrix}$$

From this, a displaced amount in the Y axis direction ΔY is calculated as |YP2-YQ2|.

(Calculating method of displacement in the rotational direction)

The displacement calculating method when a displacement exists in the rotational direction is described with reference to Fig. 18. Likewise in Figs. 16 and 17, the solid line shows the actual placing position of the glass plate and the broken line shows the teaching position. In Fig. 18, the glass plate shown by the solid line is displaced in parallel in the X and

Y axes directions, and rotational direction as compared with the glass plate at the teaching position. The method for calculating a displacement in the rotational direction is measuring a measurement angle θP3 from the initial position to P3(XP3, YP3) on the same side as P2, in addition to the points P1 and P2 on the respective sides of the glass plate as described above to calculate the coordinates in the same way as P1 and P2.

(Equation 6)

$$\begin{pmatrix} X_{P3} \\ Y_{P3} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{P3} & -\mathrm{Sin}\theta_{P3} \\ \mathrm{Sin}\theta_{P3} & \mathrm{Cos}\theta_{P3} \end{pmatrix} \begin{pmatrix} r \\ 0 \end{pmatrix}$$

From this equation, P3 (XP3, YP3) is calculated.

The side including this measurement point P3 (XP3, YP3) is rotationally displaced by a displaced amount α with respect to the side including the teaching position Q3 (XQ3, YQ3). Since the displaced amount α is an angle formed by a vector P2P3 from P2 to P3 and a vector Q2Q3 from Q2 to Q3, it is calculated as follows.

(Equation 7)

$$\overrightarrow{P2P3} \cdot \overrightarrow{Q2Q3} = \left|\overrightarrow{P2P3}\right| \left|\overrightarrow{Q2Q3}\right| \times \mathrm{Cos}\alpha$$

(Equation 8)

$$\alpha = \mathrm{Cos}^{-1}\left(\frac{\left(X_{P3} - X_{P2}\right)\left(X_{Q3} - X_{Q2}\right) + \left(Y_{P3} - Y_{P2}\right)\left(Y_{Q3} - Y_{Q2}\right)}{\sqrt{\left(X_{P3} - X_{P2}\right)^2 \left(X_{Q3} - X_{Q2}\right)^2 + \left(Y_{P3} - Y_{P2}\right)^2 \left(Y_{Q3} - Y_{Q2}\right)^2}} \right)$$

From these equation, the displaced amount α is calculated.

(Displacement compensating method)

When the glass plate is displaced in the X axis direction as shown in Fig. 16, the measurement position of the glass plate shown by the solid line is displaced by ΔX to the right of Fig. 16 with respect to the teaching position shown by the broken line. With the transporting apparatus of the present invention, if the glass plate is displaced from the shown position to the left of the figure by ΔX, the displacement can be compensated.

The same goes for Fig. 17 where the glass plate is displaced in the Y axis direction. Displacement is compensated by placing the glass place in an opposed direction to the displaced direction from the teaching position.

When the glass plate is displaced in the rotational direction, the robot is rotated by the displaced amount α in the rotational direction in the experimental glass plate coordinates of Fig. 19. The measurement points P1 and P2 are moved to P4 and P5, respectively. The coordinates of these P4 and P5 are calculated by the following equations.

(Equation 9)

$$\begin{pmatrix} X_{P4} \\ Y_{P4} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\alpha & -\mathrm{Sin}\alpha \\ \mathrm{Sin}\alpha & \mathrm{Cos}\alpha \end{pmatrix} \begin{pmatrix} X_{P1} \\ Y_{P1} \end{pmatrix}$$

(Equation 10)

$$\begin{pmatrix} X_{P5} \\ Y_{P5} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\alpha & -\mathrm{Sin}\alpha \\ \mathrm{Sin}\alpha & \mathrm{Cos}\alpha \end{pmatrix} \begin{pmatrix} X_{P2} \\ Y_{P2} \end{pmatrix}$$

From these equations, the coordinates of P4 (XP4, YP4) and P5 (XP5, YP5) can be calculated. However, although the rotational displacement can be compensated, the displacements in the X axis and Y axis directions are not compensated. The displaced amounts can be calculated by comparing the X coordinate between P4 and Q1 for the displacement in the X axis direction and comparing the Y coordinate between P5 and Q2 for the displacement in the Y axis direction. These calculated displaced amounts are used to correct the teaching position of the glass plate. In the transporting apparatus of the present invention, the displacement in the X axis direction is corrected by correcting the movable table 41, the displacement in the Y axis direction can be corrected by extending the rotating arms 16, and the displacement in the rotational direction can be corrected by rotation of the robot as described above.

While Figs. 13 to 19 treat the case of one sensor provided, a transporting apparatus shown in Fig. 20 has two placing position detecting means (sensors). The placing position

detecting means is comprised in such a manner that the position detecting sensors are provided at different distance from the pivot center of the robot. As described above, the position calculating portion calculates a displaced amount of the placing position of the end effectors 17. In the following description, the second sensor is provided outside of the aforementioned sensor and its teaching position is indicated by the coordinates V (x, x).

<Teaching method>

When the end effectors hold the glass plate at the preset reference position as mentioned above, angles and positions of sides of the glass plate detected by the position detecting sensors 110 are shown. The glass plate is held at the predetermined reference position and the end effectors are moved to the initial position, and then, the robot 14 is rotated to measure angles $\theta Q1$, $\theta V1$ from the initial position to the positions where the edges of the glass plate are detected.

These results are stored in storing means as the teaching angles $\theta Q1$, $\theta V1$. This information is used as a basis to calculate teaching positions Q1 (XQ1, YQ1), V1 (XV1, YV1) by the calculating means. The equation for calculating the teaching position Q1 (XQ1, YQ1) is the same as the aforementioned equation (2), and the equation for calculating V1(XV1, YV1) is as mentioned below. In the equation, r1 and r2 are distances from the rotational center of the robot to the optical axes of the sensors.

(Equation 11)

$$\begin{pmatrix} X_{Q1} \\ Y_{Q1} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{Q1} & -\mathrm{Sin}\theta_{Q1} \\ \mathrm{Sin}\theta_{Q1} & \mathrm{Cos}\theta_{Q1} \end{pmatrix} \begin{pmatrix} r_1 \\ 0 \end{pmatrix}$$

(Equation 12)

$$\begin{pmatrix} X_{V1} \\ Y_{V1} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{V1} & -\mathrm{Sin}\theta_{V1} \\ \mathrm{Sin}\theta_{V1} & \mathrm{Cos}\theta_{V1} \end{pmatrix} \begin{pmatrix} r_2 \\ 0 \end{pmatrix}$$

From these equations, the teaching positions Q1(XQ1, YQ1) and V1(XV1, YV1) are calculated. Further, these teaching positions are not measurement values but can be desired coordinates preset in the storing means.

Likewise, the angles of Q2, Q3, Q4, V1, V2, V3 and V4 are measured to calculate the teaching position. Displacement in the X axis direction can be calculated by each sensor as described above.

Then, Fig. 21 is utilized to explain a method of calculating displacement in the rotational direction from the teaching position based on the measurement value when two sensors are provided. In the figure, the solid line shows an actual placing position of the glass plate and the broken line shows the teaching position. In Fig. 21, the center of the glass plate is displaced from the teaching position to the coordinates U and further, the glass plate placed on the end effectors is

displaced in the counterclockwise direction around the center of the coordinates U. Each of the sensors is rotated relatively to measure the operating angles of the robot (hereinafter referred to as "θP1, θW1") from the initial position to the positions P1 (XP1, YP1), W1 (XW1, YW1) where the glass plate crosses the optical axes. As is the same with the aforementioned teaching angle, the measurement point P1 (XP1, YP1), W1 (XW1, YW1) of the glass plate is calculated as follows.

(Equation 13)

$$\begin{pmatrix} X_{P1} \\ Y_{P1} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{P1} & -\mathrm{Sin}\theta_{P1} \\ \mathrm{Sin}\theta_{P1} & \mathrm{Cos}\theta_{P1} \end{pmatrix} \begin{pmatrix} r_1 \\ 0 \end{pmatrix}$$

(Equation 14)

$$\begin{pmatrix} X_{W1} \\ Y_{W1} \end{pmatrix} = \begin{pmatrix} \mathrm{Cos}\theta_{W1} & -\mathrm{Sin}\theta_{W1} \\ \mathrm{Sin}\theta_{W1} & \mathrm{Cos}\theta_{W1} \end{pmatrix} \begin{pmatrix} r_2 \\ 0 \end{pmatrix}$$

From the coordinates calculated with the measurement values, a displacement in the rotational direction is calculated as follows. A side including the measurement points P1 (XP1, YP1), W1(XW1, YW1) is rotationally displaced by β from a side including the teaching position Q1(XQ1, YQ1), V1(XV1, YV1). This displaced amount β is an angle formed by the vector P1W1 from P1 to W1 and the vector Q1V1 from Q1 to V1, which is calculated as follows:

(Equation 15)

$$\overrightarrow{P1W1} \cdot \overrightarrow{Q1V1} = \left|\overrightarrow{P1W1}\right| \left|\overrightarrow{Q1V1}\right| \times \operatorname{Cos}\alpha$$

(Equation 16)

$$\beta = \operatorname{Cos}^{-1}\left(\frac{(X_{W1} - X_{P1})(X_{V1} - X_{Q1}) + (Y_{W1} - Y_{P1})(Y_{V1} - Y_{Q1})}{\sqrt{(X_{W1} - X_{P1})^2 (X_{V1} - X_{Q1})^2 + (Y_{W1} - Y_{P1})^2 (Y_{V1} - Y_{Q1})^2}} \right)$$

From these equations, the displaced amount β is calculated.

Hereinafter, displacement correcting method is applicable if the aforementioned α is replaced with β.

(Dust disposal)

As mentioned above, the present invention provides a thin plate transporting apparatus which is operated in the clean environment. In the transporting operation, it is desired to prevent dust generation. First, it is important to generate as little dust as possible. However, as the transporting apparatus includes movable portions, it is difficult to completely eliminate dust generation due to sliding or the like of the components. Then, it is preferable to pick up dust from each dust-generating portion of the transporting apparatus to exhaust the dust to the outside.

Fig. 22 is a partial perspective view for explaining an embodiment to prevent dust pollution in the clean environment.

Dust is generated at the robot 14 (see Fig.3) placed on the support table 13 and gathered at an exhaust duct 82a via an exhaust pipe 80 connected to the dust source of the robot 14.

The exhaust duct 82a is connected to the exhaust duct 82b and further connected via an exhaust pipe 83 which passes through the inside of the upright support member 12 and the inside of the moving table 41, exhaust ducts 82c, 82d and 82e, to the outside of the clean environment. The inside of each of these exhaust ducts 82a through 82e is subjected to suction to the outside and air or atmosphere in the exhaust ducts 82a through 82e is let out to the outside of the clean environment. In addition, various electrical wirings are preferably placed in the exhaust pipe 80 and the exhaust ducts 82a through 82e.

The exhaust duct 82a is rotatably supported by the rotational axis 81a on the support table 13, and further connected to the exhaust duct 82b via the rotational axis 81b. The exhaust duct 82b is rotatably supported by the rotational axis 81c on the upright support member 12. Accordingly, the exhaust ducts 82a and 82b are allowed to move following the movement of the horizontal support table 13, or even the vertical movement of the horizontal support table 13, by rotation of the rotational axes 81a to 81c. This configuration prevents the rotational axes 8a to 81c from moving above the horizontal support table 13, thereby avoiding the rotational axes 81a to 81f from hitting the horizontal support table 13 and the robot 14, with no contact between the floor and the like and the wiring.

The exhaust duct 82c is also connected to the moving table 41 by the rotational axis 81d and connected to the exhaust duct 82d via the rotational axis 81e. The exhaust duct 82d is connected to the exhaust duct 82e via the rotational axis 81f provided on a sliding member 84 sliding on the rail 42. As the sliding member 8a slides and the rotational axes 81d, 81e and 81f enables rotational movement, even if the support table 41 slides in the horizontal direction, the exhaust ducts 82c, 82d and 82e follow its movement thereby discharging the duct to the outside.

Although Fig. 22 deals with only the example of discharging dust from the robot 14, it is preferable that dust generated by the vertical sliding movement of the movable table 11 and dust generated by horizontally sliding movement of the moving table 41 and sliding member 84 are all collected to the exhaust ducts 82a and 82e to be discharged.

(Other embodiments)

The above description does not deal with the Y axis direction horizontally transporting apparatus. However, the transporting apparatus of the present invention is preferably provided with a horizontally moving mechanism as the transporting apparatus is for transporting a large size sheet (2 m x 2 m glass plate or the like) and therefore the distance between a plurality of cassettes and the distance between a plurality of processing chambers are often long. Specific examples of the horizontally moving mechanism of the robot 14

include a system of horizontally parallel rails and rack-and-pinion, a cableway system, a ball screw rail system, a rail running system, an air-cushion system, a magnetic levitation system and other well-known heavy lifting systems. A driving source of such a horizontally moving mechanism used here includes a servo motor, a stepping motor, a linear motor, a fluid pressure cylinder of hydraulic pressure or air pressure and other well-known driving sources.